THE IMPACT OF MEGAHERBIVORE GRAZERS ON GRASSHOPPER COMMUNITIES VIA GRASSLAND CONVERSION IN A SAVANNAH ECOSYSTEM

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ABSTRACT

Grasshoppers are sensitive indicators of the state of disturbance of grassland ecosystems. This study examined the grasshopper communities inside a game reserve, comparing those found on frequently grazed areas with communities inside plots that exclude megaherbivores. The vegetation inside the protected plots was found to differ from the openly grazed areas in terms of grass height and aerial cover, but not in % greenness or richness of forb species. Grass species varied with locality rather than grazing impact. Total numbers of grasshoppers did not differ significantly between the two contrasting areas (100.2 in vs 93.5 out), however grasshopper species richness did, with the outside, short-grass plots having on average 17 different species, (n = ?) and the inside tall-grass plots a higher mean of 24.5. Grasshopper communities responded primarily to grassheight and vegetation cover, but not to grass species or greenness of vegetation.

be more explicit

mean, n ?

INTRODUCTION

Grasshoppers are one of the predominant insect herbivores Cangon's in African savannahs (Prendini *et.al.* 1996). They play important roles in ecological processes, being major primary consumers, significant generators and transporters of nutrients, major players in energy flow, and account for a large part of the total insect biomass (Gebeyehu & Samways 2001 2002). In addition, they serve as sensitive indicators of the state of disturbance of grassland ecosystems (Prendini *et.al.* 1996) which render them very useful indicators in ecological assessments.

Orthoptera are highly mobile insects whose selection of habitat is affected by plant species composition, plant nutritional quality and morphological characteristics, availability of predator-free space and suitable oviposition sites, and microclimate (Prendini *et.al.* 1996). Such factors in turn may be strongly affected by large mammalian grazers, who can have significant effects on the structure and composition of plant communities (Bond and Loffell 2001). Vertebrate grazers form an integral part of the Umfolozi-Hluhluwe ecology, affecting the floral community structure directly through defoliation, trampling, and faecal and urinary production (Gebeyehu & Samways 2001). This in turn is expected to affect insect community structure, for which grasshoppers may be a suitable indicator group. Currently it is largely unknown as to what extent changes in vegetation composition affect local insect herbivores in the savanna biome (Gebeyehu & Samways, 2003).

This study was conducted in the Umfolozi-Hluhluwe nature reserve in Kwazulu Natal, South Africa, a grassland savanna biome described by Acocks (1988) as Lowveld and Zululand Thornveld.

One of the distinctive veld types in Umfolozi-Hluhluwe is the short-cropped lawn. These lawn environments have previously been considered to be overgrazed and thus undesirable (Bond, pers. comment). More recently however, questions have been raised regarding the sustainability of such short-grass systems. The large herbivores spend more time grazing here, which maintains a short grass length. The question now posed is whether this preferred state of grassland needs to be kept short (by management?) in order to overcome competitive invasion by taller grasses. If so, then discouraging the grazing of these patches (by, for example luring away large grazers to fresh, post-burn growth) may cause loss of the lawn grass species through a fairly rapid change to tall grassland. Some insight into the grasshopper communities prevalent in tall vs short grass areas may serve as an indication of whether or not the lawn patches are significant components of the ecosystem. If they are indeed steady state systems within the grassland biome, one may expect to find unique Orthopteran species or communities in them. Such a finding would have management implications for grazing and burning schemes. Using fire as a tool for veld management in the park is a highly contentious issue, with long-term studies investigating the suitability of different burn regimes, specifically with regards to lawn patches (Bond & Archibald, 2003).

how?

In addition to promoting a better understanding of lawn grass systems, this project makes a contribution to the knowledge on South African insect species richness. As outlined by McGeoch (2002), initiatives aimed at promoting insect conservation in the country include amongst others, identification of bioindicators, ecological landscaping, and mapping of species distributions. Information on grasshopper abundance and species richness in the distinct lawn habitats of a savanna ecosystem could contribute to insect conservation in the country. She further recognizes environmental threats to insect fauna to include fires, overgrazing, soil erosion, invasive species, and climate change - all current, relevant issues in the park, some of which may be better understood with the outcomes of this study.

The long-term effect that large herbivores have on plant (especially lawn) communities in Umfolozi-Hluhluwe is being investigated using a number of exclosures throughout the park. These exclosures have been designed to exclude mammals of various sizes, such that every set of exclosures is comprised usually of four 50m x 50m plots, each exposed to varying degrees of impact from mammals (see Methods). These sites provided suitable vegetation contrasts for the purposes of this study.

This project is based on three hypotheses:

1. Vegetation structure (viz. height and composition of grassland) affects Orthopteran community structure. (i.e. discrete Orthoptera communities are found in habitats with different grass height)
2. Plant diversity (i.e. plant spp richness) affects Orthopteran community structure. (Discrete Orthoptera communities associated with sites of varying plant diversity)
3. Lawns are steady state systems, with unique associated Orthoptera species or communities.

decimal degrees c min do not accurately describe the Reserve - are point data)

SITES AND METHODS

Umfolozi-Hluhluwe nature reserve is in central KwaZulu-Natal, South Africa (S 28°15', E 32°00' –S 28°10', E 32°06'). Umfolozi and Hluhluwe used to be two separate parks and are referred to as two ~~as~~ distinctive units of the park, even though they have been merged and are now both part of the same 'Umfolozi-Hluhluwe' game reserve.

Figure 1 diagrammatically shows the exclosures design used ~~found~~ throughout the park. Only the insides of the most heavily fenced exclosures (those excluding all herbivores larger than hares and rodents) were used in this study, providing vegetation that has not been grazed by megaherbivores since ***?. The open areas in the close proximity of the exclosures provided contrasting, frequently-grazed sampling sites.

noted in draft, ignored.

Single cable	Double cable	Upside-down game fence	Chicken wire
Excludes megaherbivores such as Rhinos	Excludes large grazers such as Buffalo, Wildebeest & Zebra	Excludes smaller grazers like Impala & Nyala	Excludes all herbivores larger than hares & rodents

Figure 1: Schematic representation of the exclosures in Umfolozi-Hulhluwe Park. Each successive camp excludes herbivores of decreasing size, while the surrounding grassland is open to all.

A lot of information is missing here

when were exclosures set up?

The six exclosures chosen as study sites were "Thoboti", "Gqoyeni", "Seme", "Maqanda", "Klazana" and "Nombali". Of these, "Thoboti" and "Gqoyeni" are found in the Umfolozi section of the park, while the other four are in the Hluhluwe section. Any further use of the word 'plot' will refer to a particular sampling area, i.e. either the inside or the immediate outside of any of the above exclosures.

Vegetation Sampling:

Ten 1m x 1m quadrats were used to sample grass height, percentage greenness of grass, percentage arial cover, and number of forb species. A mean of three readings taken per 1m x 1m quadrat was used in calculating the mean grass height over the ten quadrats. Measurements were taken with a disc pasture metre, and represent the maximum height reached by the majority of stalks in a stand of grass.

Both percentage greenness and percentage arial cover were subjectively assessed for the ten quadrats by the same person throughout the study.

Grass species occuring inside the exclosures were obtained from a database of the "Zululand Grass Project".

Grasshopper Sampling:

Field work was carried out over the last two weeks in April 2003 - at the end of the rainy season, when grasshopper abundance would have been at a maximum (Picker, pers. comment). Sampling was carried out using sweep-nets. A species accumulation curve was drawn for an initial sample to assess the appropriate collecting effort, and was found to flatten out at fourteen transects. Subsequently ~~the~~ fourteen transects, each of 50 sweeps, were sampled in every plot. The catch of each set of 50 sweeps was immediately bagged, labelled and frozen within four hours. Samples were kept frozen until they were counted and sorted into morphospecies. Samples from all fourteen transects were pooled for each plot. A reference collection was made to include ~~including~~ all ~~the~~ species ~~was~~ pinned, and specimens were identified by M. Picker from the Orthoptera collection at the National Collection of Insects in Pretoria. Although a large number of nymphs were caught, most of them could not be identified with certainty, and so only the adults were included in the analyses. Grasshopper nymphs are notoriously difficult to sample (D. Brown, pers. comm.)

Data analyses were carried out with the computer software packages PRIMER (Plymouth Routines in Multivariate Ecological Research, version 5) (Clarke and Gorley 2001) and STATISTICA 6 (Statsoft Inc, 1984-2002).

various parameters

Statistical comparisons of ~~the~~ various vegetation parameters (i.e. grass height; % aerial cover; % greenness; number of forb species) inside vs outside the exclosures were performed using STATISTICA.

Grass species data was obtained from the Zululand Grass Project database, and was used later in analyses when matching environmental variables with changes in the grasshopper communities.

T-tests for independent samples were run for species richness and total grasshopper numbers inside vs. outside exclosures.

T~~wo separate PRIMER~~ ~~D~~ dendrograms were constructed to show similarities between the plots with respect to grass species and grasshopper communities, based on Bray-Curtis similarities from square-root transformed data. An MDS ordination (~~N~~ non-metric multi-dimensional scaling) gave a 2-dimensional map of the plots, depicting their similaritie~~s~~ i.t.o. grasshopper species composition. SIMPER routines were run for both the grass species and grasshopper communities, to examine which species contributed to the observed patterns of species distributions. One-way analyses of variance were run to varify distributional patterns of grass species composition.

T-tests for independent samples were run to examine whether patterns of grasshopper communities were caused by differences in species richness or in abundance. ?

RESULTS

In this section, the exclosures are frequently referred to by the code names given in Table 1 below.

to methods

Table 1. Code names used for the sites. Each code name is usually followed by in or out, indicating whether inside or outside the exclosure.

Code	Site	Location
GQ	Gqoyeni	Umfolozi
TH	Thoboti	Umfolozi
Kla	Klazana	Hluhluwe
Nom	Nombali	Hluhluwe
Seme	Seme	Hluhluwe
Maq	Maqanda	Hluhluwe

Vegetation

T-tests independent by variables indicated that grass height and cover differ~~ed~~ed significantly between inside and outside the exclosures, but greenness and richness of forbs ~~do~~ did not (Table 2).

where is table 1?

Table 2. Vegetation characteristics inside vs outside exclosures (N=6, d.f.=10; mean±1 SD).

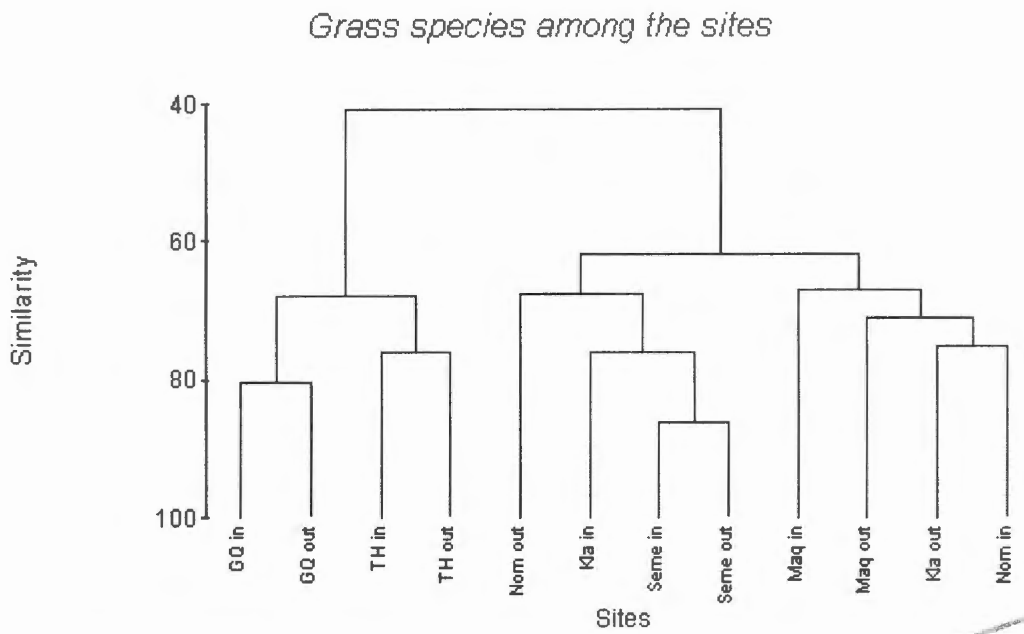
Vegetation variable	In	Out	t-value	p
Grass height	68.57±15.25	18.52±10.54	6.61	6×10^{-5}
% aerial cover	80.05±9.29	55.75±14.29	-3.41	0.0067
% greenness	63.92±25.4	52.58±25.8	-0.77	0.46
no. forb spp	8.6±10.43	12.08±13.44	-0.50	0.59

Should have called it App 1!

Appendix 2 lists the more common grasses found in the different exclosures.

PRIMER was used to construct the dendrogram showing similarity between the plots with respect to their grass species (Figure 2). It shows that locality has a greater influence than treatment (level of grazing) in determining grass species composition, with sites separating out clearly at the 60% level for the two parts of the reserve. Next the SIMPER routine was applied to examine which species of grasses contributed most to the observed similarities (within the Umfolozi sites and those in Hluhluwe, Table 3.0), and to the dissimilarities between the two groups of Umfolozi and Hluhluwe plots (Table 3.1), in other words which species were the best definers of the Umfolozi vs Hluhluwe grasses parts ~~of the reserve~~. *Themeda triandra, Panicum colloratum and* P. ~~*Panicum*~~ *maximum* are the three most comst common grass in Umfolozi, while *Bothriochloa insculpta, Digitaria longifolia* and *Sporobolus pyramidalis* are characteristic of Hluhluwe. Of these grasses, *Themeda triandra, Sporobolus pyramidalis* and *Digitaria longifolia* are the greatest instigators causing the difference in grass species composition between the two parts of the reserve.

A one-way Anova via the ANOSIM routine varified the significance of the difference between grass species composition between Umfolozi and Hluhluwe (global R = 0.954; significance level p = = 0.002).



they are not plots, but branches

Figure 2. Dendrogram showing similarity between plots i.t.o. grass species. The four plots on the left-hand branch are in the former Umfolozi part of the park, while those on the right-hand branch are on the Hluhluwe side. (Group average linking of Bray-Curtis similarities calculated on the square-root-transformed abundance data of grasshoppers, using PRIMER)

Table ~~*10*~~ 3. Grass species contributions to similarities within Umfolozi (a) and Hluhluwe (b) sites. Av. Abund = average abundance (of total); Av. Sim = average similarity (of total); Contrib% = percentage contribution by the species to similarity among the relevant (Umfolozi or Hluhluwe) sites.

(a) Umfolozi:

Species	Av.Abund	Av.Sim	Contrib%
Themeda triandra	43.95	34.47	56.14
Panicum colloratum	10.58	8.13	13.24
Panicum maximum	13.60	6.47	10.54
Aristida congesta	7.82	3.59.	5.84
Eragrostis surberba	8.63	3.45	5.62
Average similarity: 61.41			

(b) Hluhluwe:

Species	Av.Abund	Av.Sim	Contrib%
Bothriochloa insculpta	17.19	12.30	23.82
Digitaria longifolia	17.85	9.76	18.89
Sporobolus pyramidalis	18.84	8.56	16.56
Panicum maximum	14.03	5.94	11.50
Themeda triandra	13.33	5.42	10.49
other	7.41	4.58	8.87
Average similarity: 51.66			

Table 3.1. Grass species contributions to dissimilarity between Umfolozi and Hluhluwe sites. Av. Abund = average abundance (of total); Av. Sim = average similarity (of total); Contrib% = percentage contribution by the species to dissimilarity between Umfolozi and Hluhluwe sites.

	Umfolozi	Hluhluwe		
Species	Av.Abund	Av.Abund	Av.Diss	Contrib%
Themeda triandra	43.95	13.33	15.83	22.60
Sporobolus pyramidalis	0.17	18.84	9.34	13.32
Digitaria longifolia	0.00	17.85	8.92	12.73
Bothriochloa insculpta	3.36	17.19	7.14	10.18
Panicum maximum	13.60	14.03	6.53	9.32
Panicum colloratum	10.58	0.17	5.20	7.43
Aristida congesta	7.82	0.00	3.91	5.58
Eragrostis surberba	8.63	2.07	3.57	5.10
Eragrostis curvula	0.00	6.45	3.23	4.61

Average dissimilarity = 70.08

There is no table 6. Appendix 1!

Grasshoppers

A total of 1162 adult grasshoppers and 37 different morphospecies were collected at the 6 sites. The grasshopper species sampled are listed in ~~Table 6~~. The pooled number of adults were recorded for each plot, and the data used for total abundance and species richness. A method!

A t-test for independent samples was run to compare both species richness and total numbers of grasshoppers ~~in vs~~ out what? out (Table 7). Species richness differed significantly, with the insides having more species ($\bar{x}$ = 24.5) as opposed to out ($\bar{x}$ 17). Total numbers were similar for in and out, with a mean of 100.2 for in and 93.5 for out. ($\bar{x}$, n, kk)

The PRIMER CLUSTER routine produced a Multidimensional Scaling (MDS) plot and a dendrogram (Figures 3.0 and 3.1 respectively) which revealed that the greatest variation in grasshopper communities is between inside and outside the exclosures with virtually no influence of locality ("in" and "out" respectively). STATISTICA t-tests for independent samples indicate that this difference is probably primarily due to differences in species richness (t = -3.23; p = 0.009) rather than differences in abundance when all treatments for all six sites were compared (t = -0.426; n = ? p = 0.679). The SIMPER routine was used to investigate which species are responsible for the community patterns. Table 4.1 lists those species most characteristic of in plots, Table 4.2 those of out plots, and Table 4.3 the main contributors to dissimilarity between the in and out communities. *Comacris semicarinatus, Orthochtha dasycnemis* and *Tylotropidius gracilepes* are characteristic of the tall-grass in plots, while *Trilophidia contubeta, Comacris semicarinatus* and *Humbe tenuicornis* are important species of the communities outside the exclosures. Table 4.4 lists those species exclusive to either the in or the out plots. Obtained from a simple presence/absence analysis of the grasshopper data in Excel it shows the in plots to have sixteen endemic species and those outside to have only four.

but not indicator species

This should not have been mentioned!

Figure 3.0. MDS ordination based on grasshopper abundance data, using Bray-Curtis similarities calculated on the square-root-transformed data, using PRIMER. Plot names are coded by their initial letter, e.g. 'Si' = Seme in.

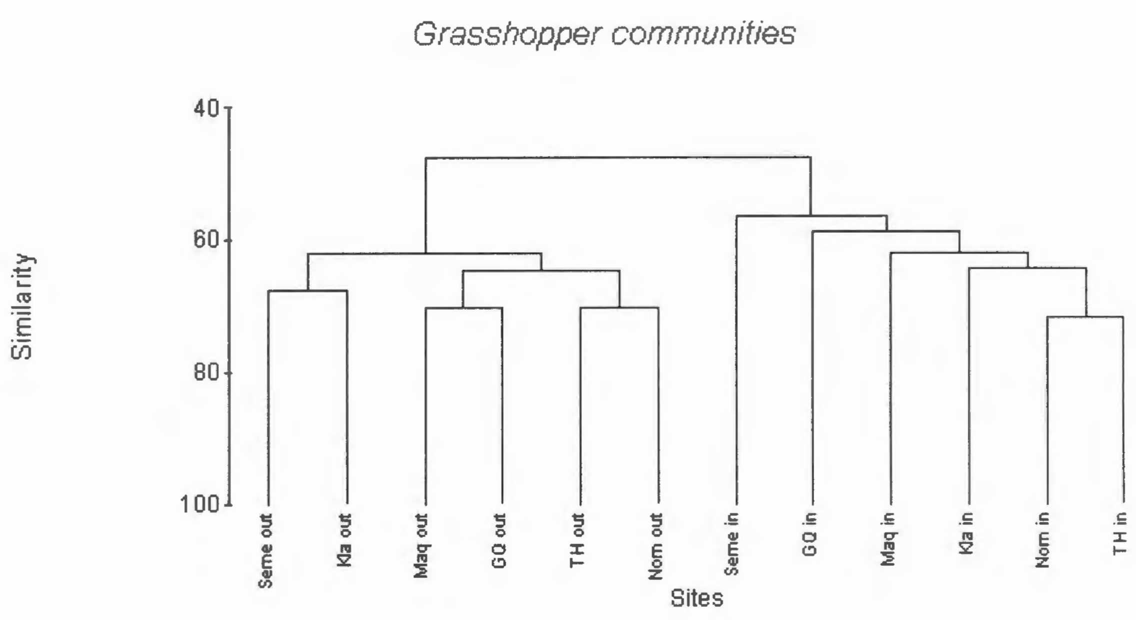


Figure 3.1 Dendrogram showing similarity between plots based on grasshopper abundance data. (Group average linking of Bray-Curtis similarities calculated on the square-root-transformed data, using PRIMER)

Table 4.1. Grasshopper species contributing most to similarity among all the in communities.

Name	% contribution	
Comacris semicarinatus	18.9	1.27
Orthochtha dasycnemis	17.7	1.24
Tylotropidius gracilipes	7.4	0.86
Catantops melanostictus	6.2	
Humbe tenuicornis	5.8	
Catantops spp	5.5	
Paracinema tricolor	5.5	

Table 4.2. Grasshopper species contributing most to similarity among all the out communities.

Name	% contribution
Trilophidia contubeta	28.7
Comacris semicarinatus	20.6
Humbe tenuicornis	15.2
Tmetonota	10.0
Oedalis carvalhoi	5.7

Table 4.3. Grasshopper species contributing most to dissimilarity between the in vs out communities.

Name	% contribution
Trilophidia contubeta	14.5
Orthochtha dasycnemis	7.9
Comacris semicarinatus	6.9

Table 4.4 Endemic grasshopper species to inside and outside the plots.

In	Out
Mesopis laticornis	*Acrida sulphuripennis*
Tylotropidius congoensis	*Morphacris* spp.
Parga xanthoptera	*Oedalis carvalhoi*
Leptacris monteiroi	unidentified morphospecies 47
Clonia	
Oedalis spp2	
Cataloipus spp	
Afroxyrrhepes procera	
Ornithacris spp	
Eucoptacra spp	
Clonia spp	
Lophothericles	
Clonia	
Unidentified morphospp. 5c, 40b and 29	

Environmental variables affecting grasshopper communities

for methods

Bubble plots of each of the environmental variables were placed on the PCA (Principle Component Analysis) points reflecting the grasshopper community patterns across the plots (Figure 4). These show grass height to be the closest matching variable. This finding is supported by a Spearman's rank correlation by the BIO-ENV procedure (normalised Euclidean

explaining what?

distance; data untransformed), which produced a correlation of 0.611 for grass height to community patterns, with the second scoring variable being % cover at 0.200. Table 5 lists all the correlations.

Table 5. Spearman's rank correlation coefficients matching environmental variables with grasshopper community patterns

Variable	R^2	P
mean grass height	0.611	
% cover	0.200	
% greenness	0.001	
forb spp richness	0.002	
mean grass height + % cover	0.568	

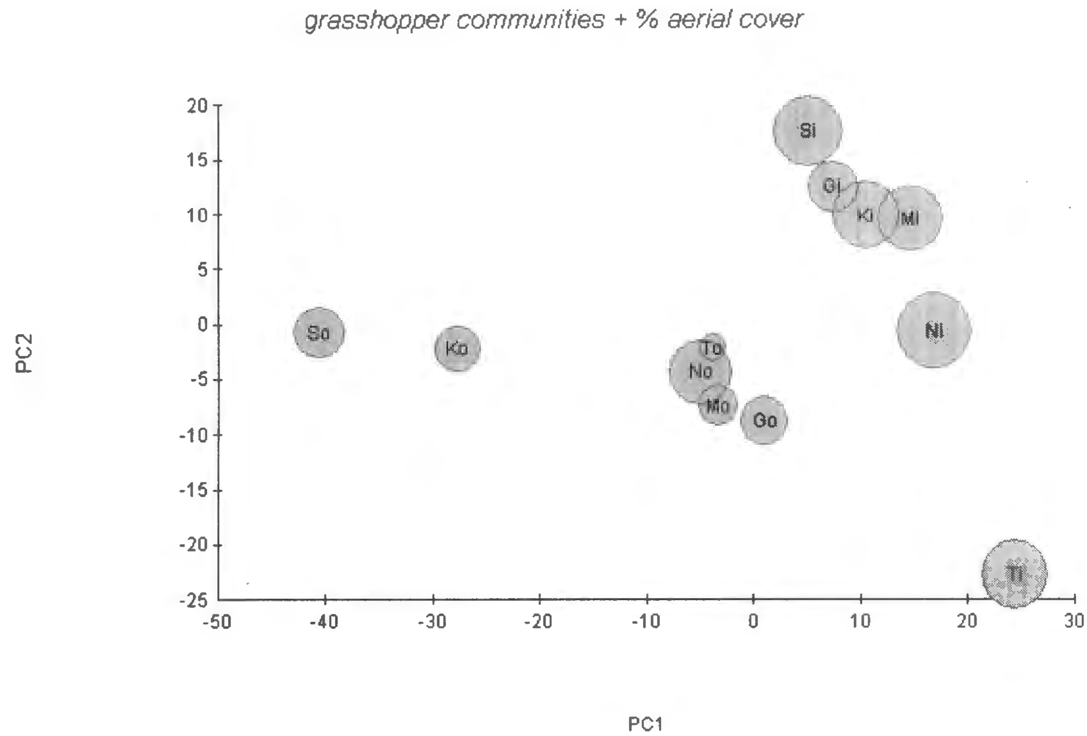
Table 7. Results of t-tests for independent samples comparing in and out i.t.o. species richness and numbers of grasshoppers (STATISTICA)

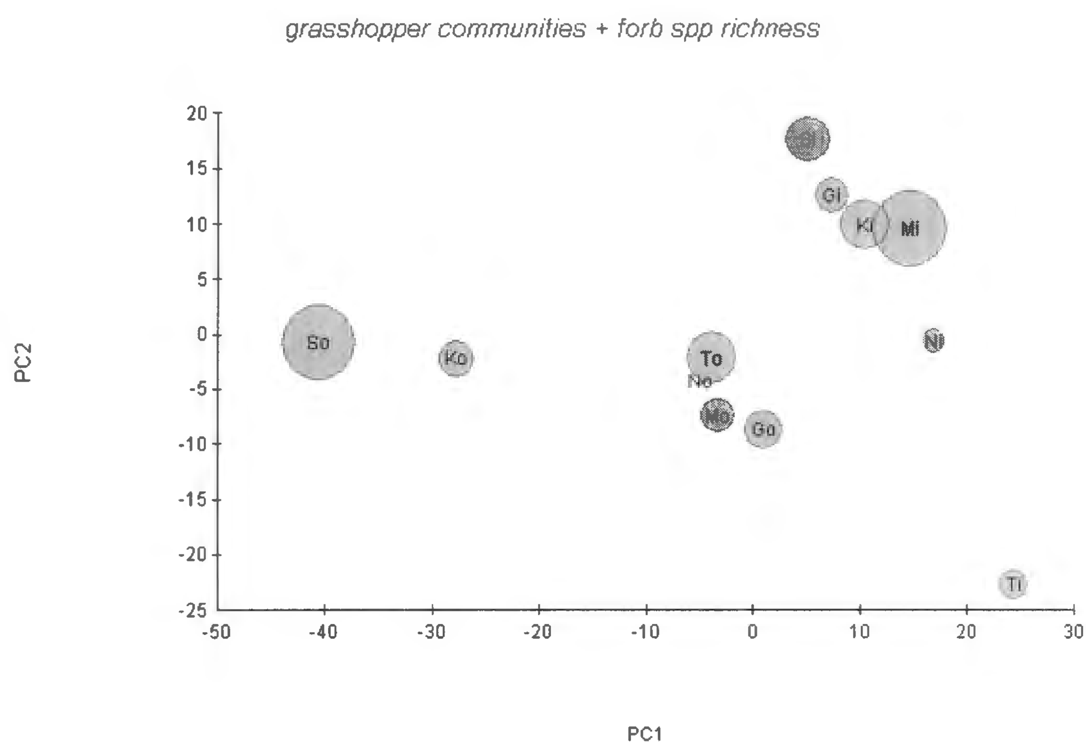
	In	out	t-value	df	P	std dev in	std dev out
Spp richness	24.5	17.0	-3.23	10	0.009	2.95	4.86
Total number	100.2	93.5	-0.426	10	0.679	35.59	14.14

where are $\bar{x}$ values?

~~Table (7) is never mentioned in the text~~ ok

Figure 4. Bubble PCAs matching environmental variables to grasshopper communities (PRIMER).





DISCUSSION

Grasshopper sampling

2001?

Visual counts has been the preferred method for a number of previous studies (e.g. Samways and Kreuzinger 2001; Gebeyehu and Samways 2002; Prendini et.al. 1996; Samways and Moore 1991), since "it provides an accurate estimate in a short period of time" (Prendini et.al. 1996). Samways and Moore (1991) 1990? found it to give the greatest species richness and diversity when compared to sweeping, drop-netting and Malaise-trapping.

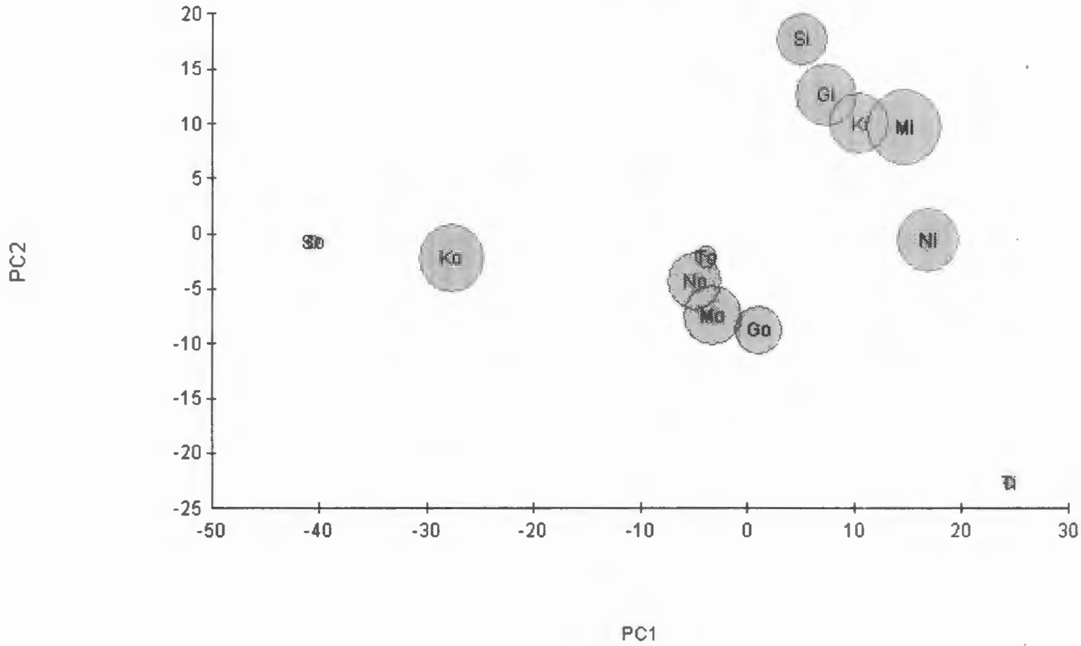
Once in the field, it was decided to sample with sweep nets since the thick, tall, grass stands inside the exclosures as well as high numbers of grasshopper species and individuals and the cryptic nature of some species made visual identification extremely difficult. We also identified the possibility of recounting insects that were flushed on a previous transects with the visual method, since our transects were by necessity close to one another in order to fit into the exclosures. Sweep-netting allowed us to sample with consistent effort and ruled out the danger of recounting the same grasshopper. It also allowed us greater accuracy with identification than visual sampling. Prendini et.al. (1996) identify sweeping to provide poor estimates of absolute abundance but good estimates of relative abundance, and therefore suitable for investigating differences in grasshopper species composition and relative abundance, and to be the most practical means of sampling large areas of tall and/or thick grass. Evans et.al. (1983) recognise that sweep sampling may give biased estimates due to variation in susceptibility of different species to being swept, and provide poor estimates of how relative numbers of grasshoppers change with the seasons at a given site. They nonetheless conclude that sweeping "provides a fairly accurate portrayal of the relative abundances of the grasshopper species at any one place and time". Sweeping appears to be the most appropriate sampling method in this study, considering that it is mainly concerned with variations in species composition and relative abundance between the plots.

As described by Dempster (1963), grasshopper populations are largely influenced by weather (humidity, rainfall and temperature), natural enemies (disease, parasites and predators), and migratory movement. out of context

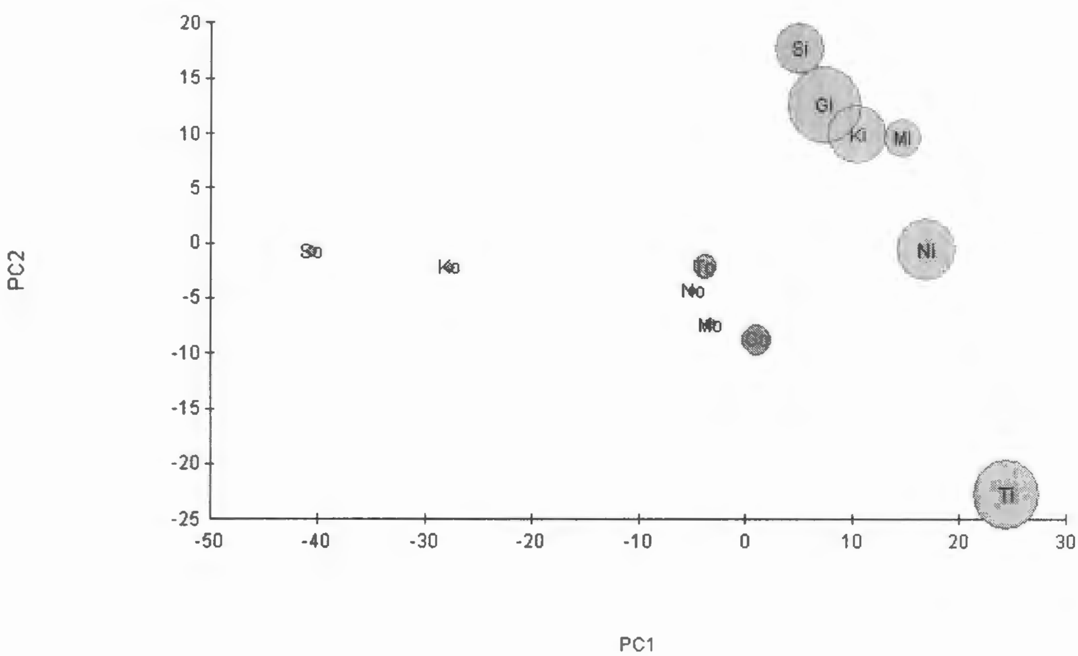
Nonetheless, this study is a comparative one in which all plots were subjected to very similar environmental conditions, and unlikely to have been affected by large-scale migrations.

In a study on grasshopper responses to different grazing intensities inside vs outside the Umfolozi-Hluhluwe reserve (Samways and Kreuzinger 2001), a total of 41 species were recorded, using visual and acoustic sampling methods. But no mention is made of how this compared to the findings of this study!

grasshopper communities + greenness



grasshopper communities + grass height



Results

The spatial distribution of grass species - i.e. variation between the former Umfolozi and Hluhluwe parts of the park as opposed to differences between inside and outside the exclosures - may indicate that the grasses respond more to environmental variables such as rainfall, temperature, or soil types. Such a speculation requires further inspection which has not been covered in this study. But – this study provides evidence for this! But not mentioned here!

Not surprisingly, grass height and aerial cover were noted to differ significantly between inside and outside the exclosures. The insides of the exclosures have been shielded from megaherbivore impact for a number of years, and it appears to have resulted in dominance of tall, so-called bunch grasses, whereas the surrounding areas open to megaherbivores typify lawn patches. This prompts questions about the role megaherbivores play in shaping vegetation structure in grassland savannahs, and the interaction between these two types of grasses. In other words, do lawn-type grasses require to be grazed in order to overcome competition from the bunch grasses? And furthermore, do they represent stable-state systems that provide unique habitats for host-specific herbivores, most commonly invertebrates (Crawly 1983)? The dynamics involved in the bunch-lawn grass interplay have been examined in a study by Bond and Archibald (2003), in which they have linked grazing patterns and burn regimes, and related these to the prosperity of lawn patches. As Gebeyehu and Samways (2003) state, "the extent to which changes in vegetation composition affected by grazing management regimes affects local insect communities, is largely unknown". Knowledge of sensitive indicator groups such as grasshoppers in the lawn areas may add valuable insight into the importance of lawns in grassland savannah, and help improve effective veld management regimes in the park and elsewhere. both of a quote ??

Elaborate!

The findings of this study show that more diverse communities (mean no. of spp in ~~of~~ was 24.5 vs out of 17.0) and a slightly greater number of grasshoppers (although not significantly so) are supported by the vegetation inside the exclosures than outside. This may be related to a greater grass height and percentage cover inside exclosures, and does not appear to be affected much by grass species, forb diversity, or greenness of vegetation; a finding compatible with that of Samways and Kreuzinger (2001) and Gebeyehu and Samways (2002). The grasshoppers also do not appear to respond significantly to variations in grass species or any other possible variation between Umfolozi and Hluhluwe vegetation. Thus grasshopper communities appear to respond to changes in vegetation structure, brought about by changes in grazing intensity. The study by

Kreuzinger and Samways (2001) in the same geographical area supports this notion, having found that "vegetation physiognomy rather than species composition of the grass and forb community, was most significant for grasshoppers", and furthermore that grasshopper density increased with decreased grazing pressure. Gebeyehu and Samways (2003) found that rotationally-grazed sites supported a high abundance and species richness compared to continuously-grazed sites.

Although more grasshopper species inhabited the tall-grass, well-covered areas than the sparser lawn patches, there are nonetheless short-grass specialists that are not found in the bunch grasses. *Trilophidia contubeta* and *Comacris semicarinatus* feature as important contributors (28.7% ~~and 20.6% respec~~tively) to the distinguished short-grass communities, and both are discriminate species which the ~~between~~ tall and short grass communities. A greater number of species were found to be endemic to inside the exclosures (sixteen species) than outside (four species). Since the insides and outsides of the exclosures are separated only by a fence easily crossed by the insects, this result may be impaired by an edge effect. Interestingly, none of the four endemic out species are listed as major contributors to the short grass communities identified by the PRIMER program. WHY? low #s?

The fact that lawn patches *do* host unique grasshopper species lends support to the theory that these areas are stable state systems rather than an undesirable outcome of overgrazing. This should be a noted consideration in veld management decisions for the park, particularly with regards to burn regimes. Furthermore, Dempster (1963) states that grasshoppers show "duality in ecological requirements" during different stages of their life cycle, and reports that areas supporting large populations of grasshoppers frequently have a mosaic vegetation with short, sparse and tall, lush vegetation in close proximity. The lawn patches in the reserve may play an important role in maintaining biodiversity, and may be crucial to certain stages in the lifecycle and therefore to the reproductive success of certain species of grasshoppers.

overgrazed areas may also have the same spp - should have compared with Kreuzinger & Samways (2001).

Cited in text, not in ref. list: Acocks (1988)
Bond + Archibald (2003)
Clarke + Gorley (2001)

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not in text.

Appendix 1. Grasshopper species sampled

Family	Subfamily	Scientific name
Acrididae	Tropidopolinae	*Afroxyrrhepes procera*
	Acridinae	*Acrida propinqua*
		Acrida sulphuripennis
		Acrida turrita
		Comacris semicarinatus
		Cannula gracilis
		Morphacris spp.
		Orthochtha dasycnemis
	Oedipodinae	*Oedalis carvalhoi*
		Oedalis spp.
		Oedalis spp.2
	Gomphocerinae	*Mesopis laticornis*
		Dnopherula cruciata
		Rhaphotittha levis
		Parga xanthoptera
		Brachycrotaphus tryxalicerus
		Paracinema tricolor
		Paracinema/Jasinema (not sure of genus)
		Gymnobothrus spp.
	Hemiacridinae	*Leptacris monteiroi*
	Oedipodinae	*Humbe tenuicornis*
		Trilophidia contubeta
		Gastrimargus
	Coptacridinae	*Eucoptacra* spp.
	?	*Anthermus granosus*
	?	*Tmetanota*
		morphospp 1-7 (unidentified)
Lentulidae	?	morphospecies 1 ?
Pamphagidae	?	morphospecies 2
	Eypreprocneminidae	*Cataloipus spp.*
		Tylotropidius gracilipes
		Heteracris spp.
		Cataloipus cognatus
		Tylotropidius congoensis
	Catantopinae	*Phaeocatantops decoratus*
		Catantops melanostictus
		Catantops sp. 1
		Catantops sp.2
	Cyrtacanthacrinae	*Ornithacris sp.*
		Cyrtacanthacris aeruginosa
Tettigoniidae	Conocephalinae	*Conocephalus maculatus*
		Clonia spp
Eumastacidae	?	*Lophothericles*
Pyrgomorphidae	?	*Zonocerus elegans*

total cover (?) of grasses in

Appendix 2. Grasses at the exclosures (% contributed ~~to~~ each plot)

	GQ in	GQ out	Maq in	Maq out	Kla in	Kla out	TH in	TH out	Nom in	Nom out	Seme in	Seme out
%Themeda triandra	57.0	52.9	0.3	0.0	24.7	4.3	43.9	22.0	2.7	20.8	36.2	17.7
% Panicum maximum	29.1	14.5	42.3	15.7	23.5	16.1	7.8	2.9	10.7	0.4	0.2	3.5
%Sporobolus pyramidalis	0.0	0.7	9.5	49.6	1.5	33.1	0.0	0.0	28.6	21.4	1.3	5.8
%Bothriochloa insculpta	0.7	0.7	15.3	4.6	11.5	20.6	11.6	0.5	35.2	16.9	14.7	18.6
%Digitaria longifolia	0.0	0.0	6.3	19.9	17.4	4.8	0.0	0.0	19.8	1.1	36.2	37.2
%other	3.0	2.1	11.6	2.3	8.8	6.2	6.8	12.9	0.2	15.1	7.5	7.6
%Urochloa mosambicensis	0.7	4.2	0.0	0.0	0.2	2.9	1.0	0.0	0.0	0.0	0.0	0.0
%Eragrostis curvula	0.0	0.0	14.3	7.4	9.3	6.0	0.0	0.0	0.8	7.6	1.1	5.2
%Eragrostis surberba	2.0	7.3	0.0	0.0	0.5	2.6	3.7	21.5	1.1	5.8	2.4	4.1
%Panicum colloratum	6.0	9.0	0.0	0.0	0.2	0.5	12.9	14.4	0.0	0.0	0.4	0.2
%Aristida congesta	0.7	8.7	0.0	0.0	0.0	0.0	5.4	16.5	0.0	0.0	0.0	0.0
%Justicia flava (forb)	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%Digitaria argyrograpta	0.0	0.0	0.0	0.6	0.0	2.2	6.8	9.2	0.0	0.4	0.0	0.0
%Chloris gayana	0.0	0.0	0.3	0.0	2.4	0.7	0.0	0.0	1.0	10.6	0.0	0.0
%Blepharis intergrifolia (forb)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

→ italics.